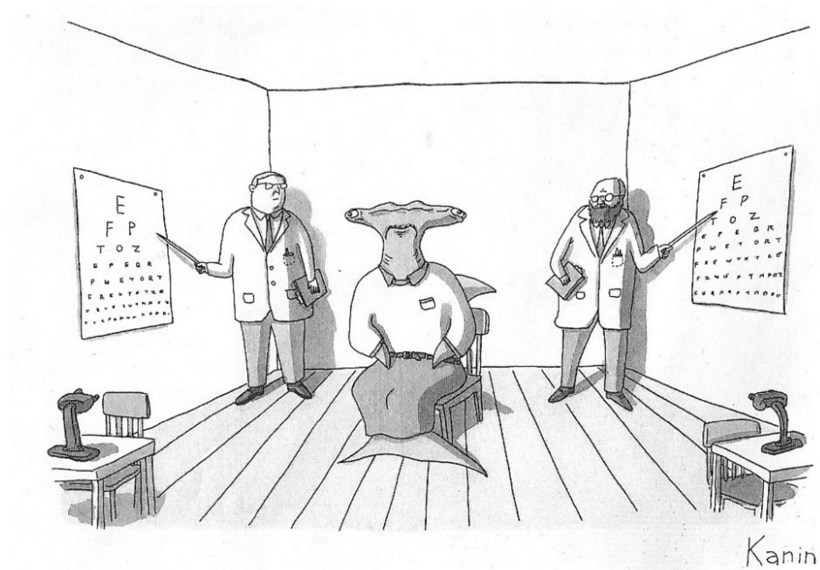
Binocular Vision

- **Forward-facing eyes allow visual fields of 2 eyes to overlap.**

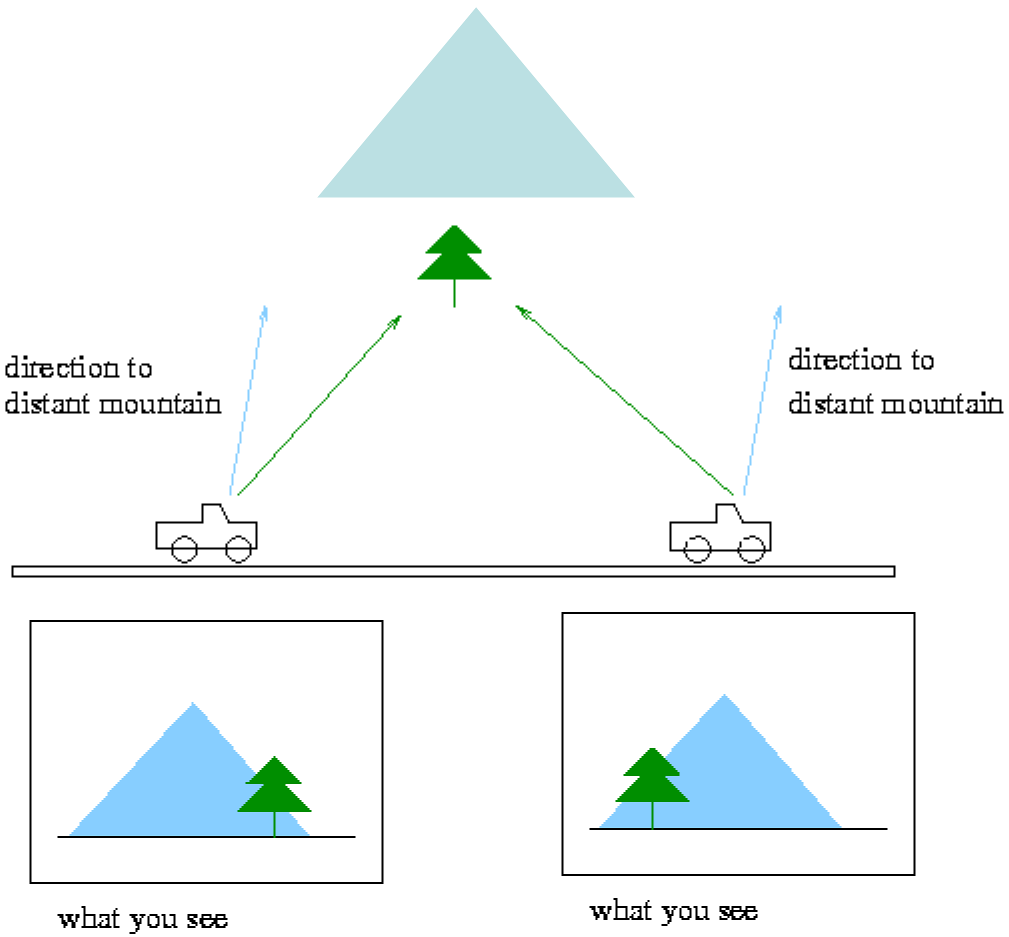
- **2 slightly different views - one percept.**

- **Allows estimate of depth.**

- **Wiring in brain brings information from 2 eyes to one spot in the brain.**

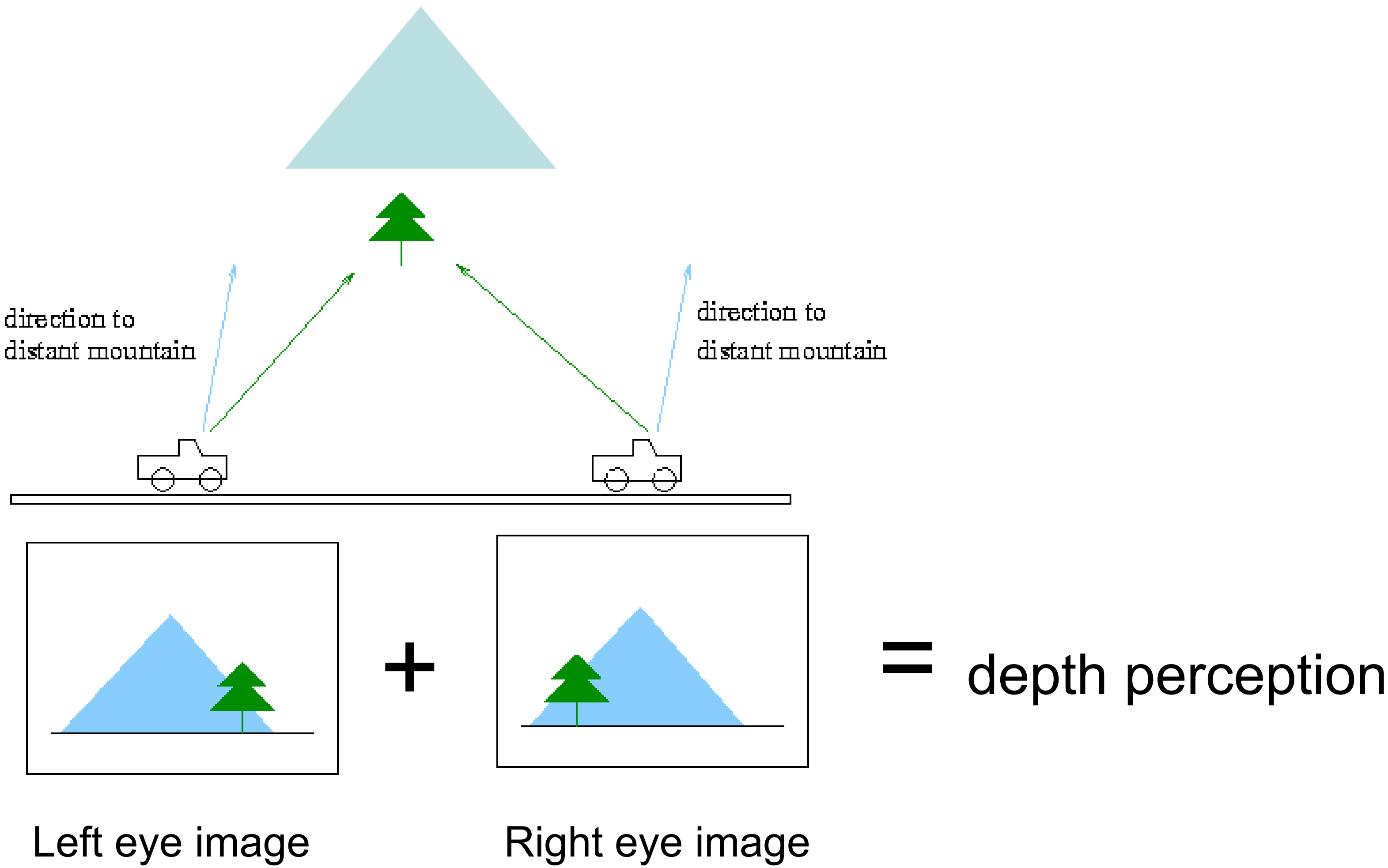


Parallax



Try this with two hands, one far behind the other and slightly to one side: look at the gap between your hands with one eye shut, then the other

Binocular vision



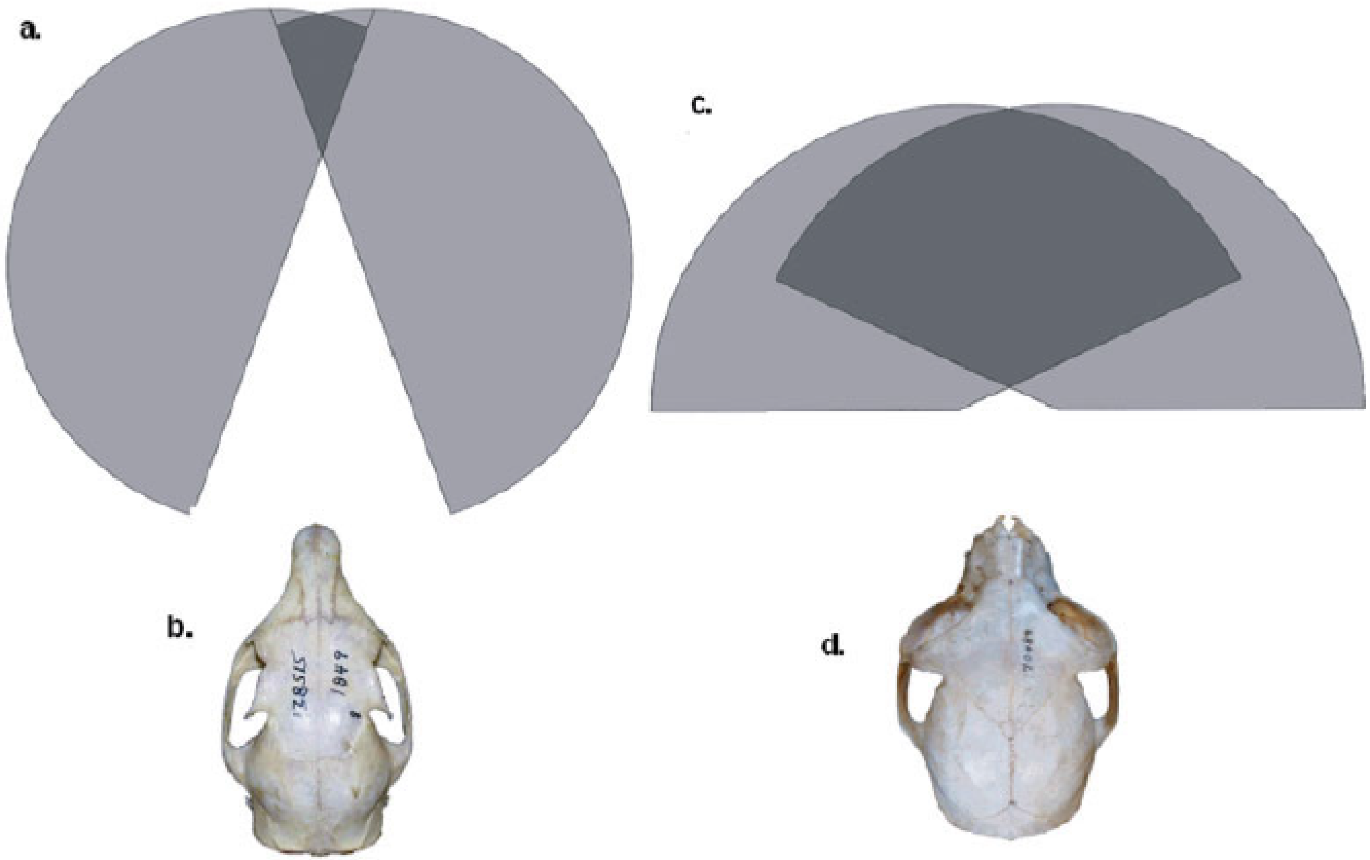


Fig. 1. Hypothesized relationship between orbit orientation and visual field overlap. **a:** Panoramic visual fields are associated with monocular visual fields (lighter-shaded regions) that are associated with small regions of binocular overlap (darker-shaded region). **b:** Skull of the squirrel *Sciurus carolinensis*, which has laterally facing orbits and a large panoramic visual field. **c:** Mammals with substantial binocular visual fields are associated with relatively abbreviated monocular visual fields (lighter-shaded regions) compared with the regions of binocular overlap (darker-shaded region). **d:** Skull of the strepsirrhine primate *Propithecus verreauxi*, which has convergent (similarly facing) orbits and possibly a large binocular visual field. Skulls not to scale.

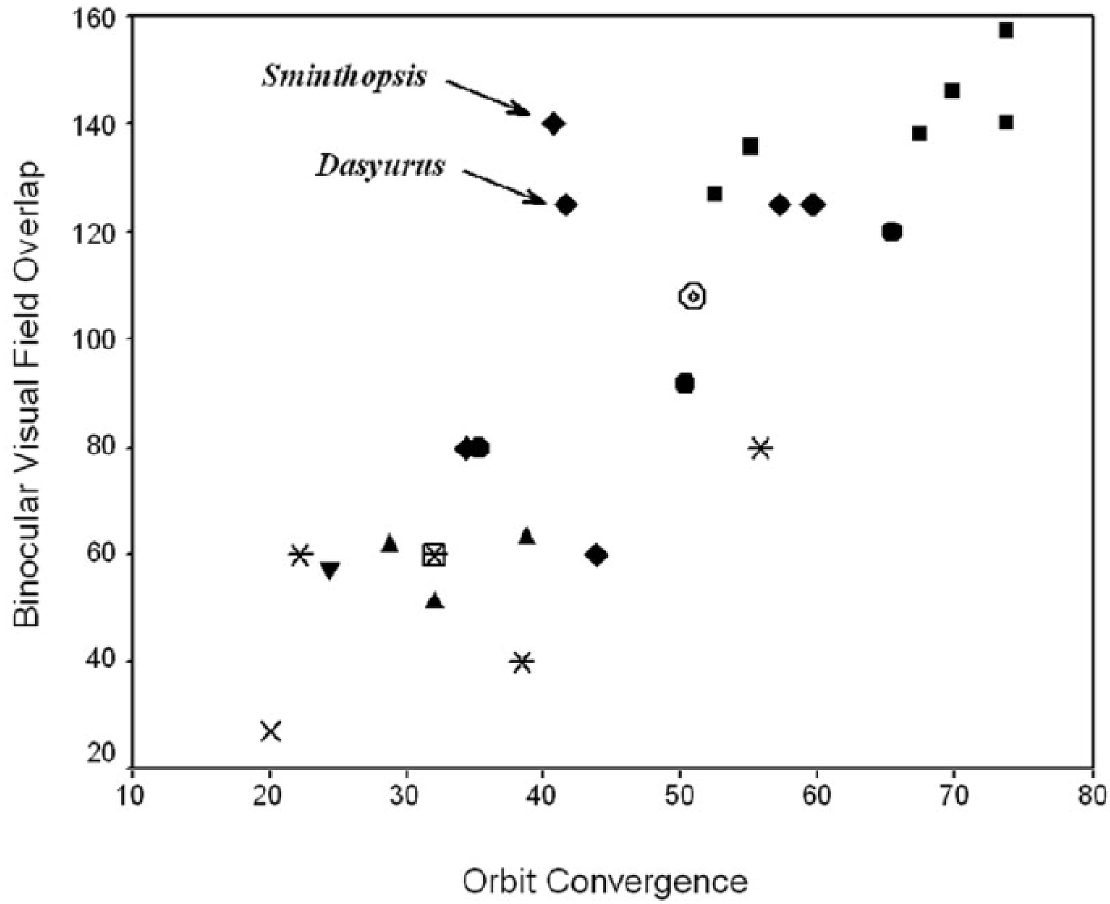
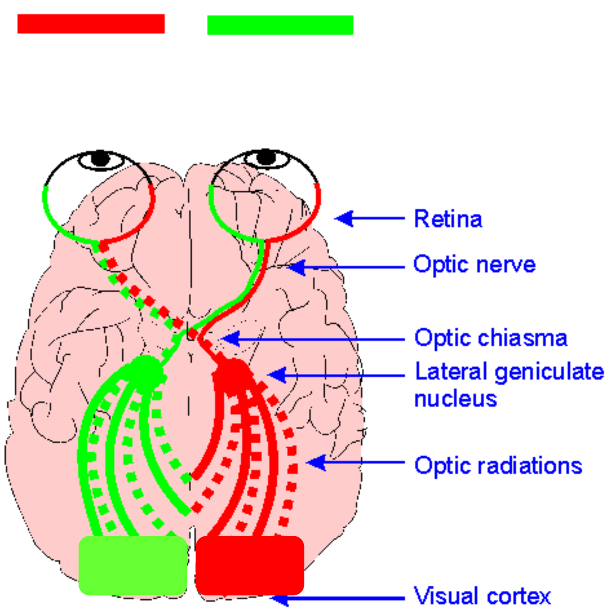


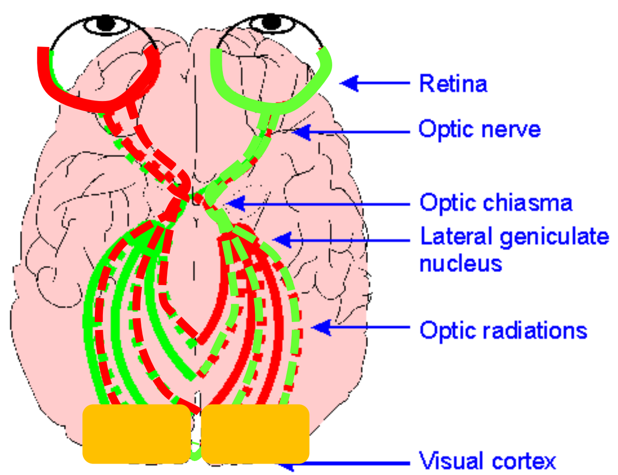
Fig. 4. Correlation between orbit convergence and binocular visual field overlap. Both variables are presented in degrees. The fitted line is the expected line of angular similarity between the variables. The outliers, *Sminthopsis crassicaudata* and *Dasyurus hallucata*, are illustrated. ▲, Artiodactyla; ●, Carnivora; ◎, Chiroptera; ×, Lagomorpha; ◆, Metatheria; ▼, Perissodactyla; ■, Primates; ✳, Rodentia; □, Scandentia.

Getting information from both eyes together:

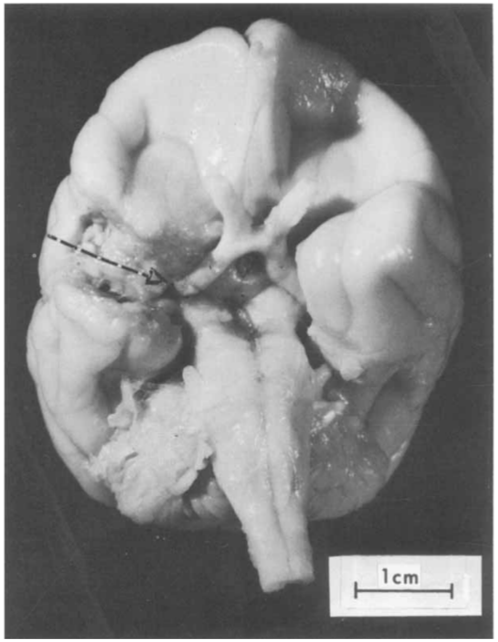
Visual field

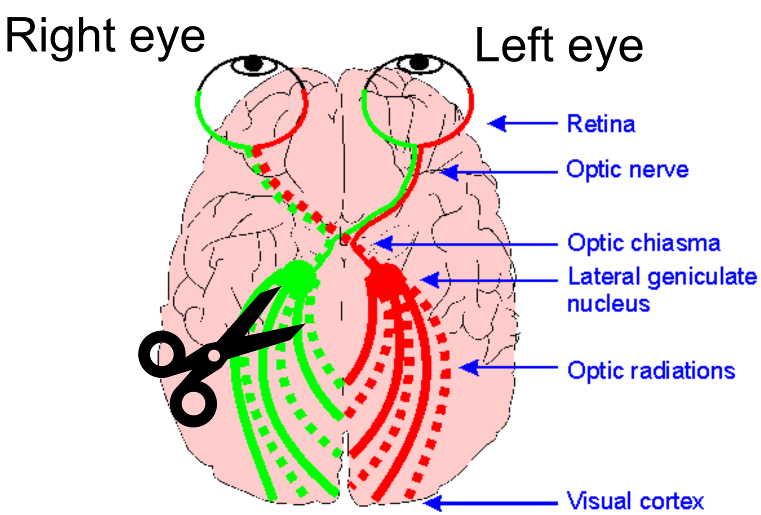


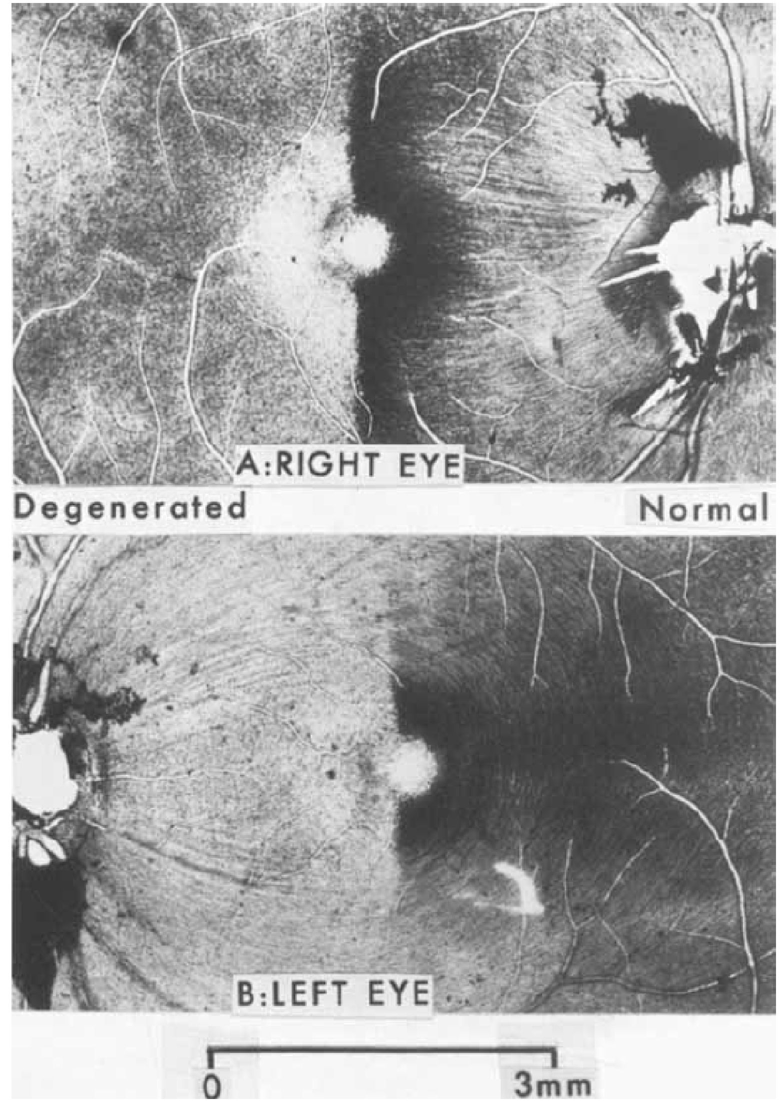
Eye specific projections

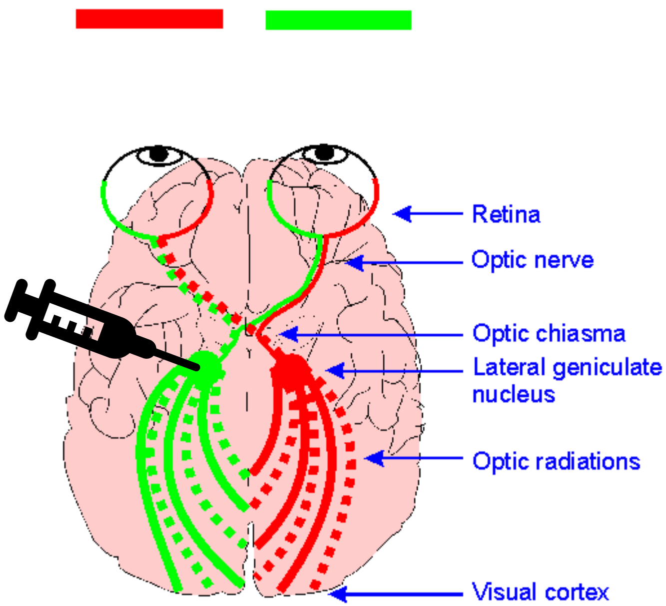


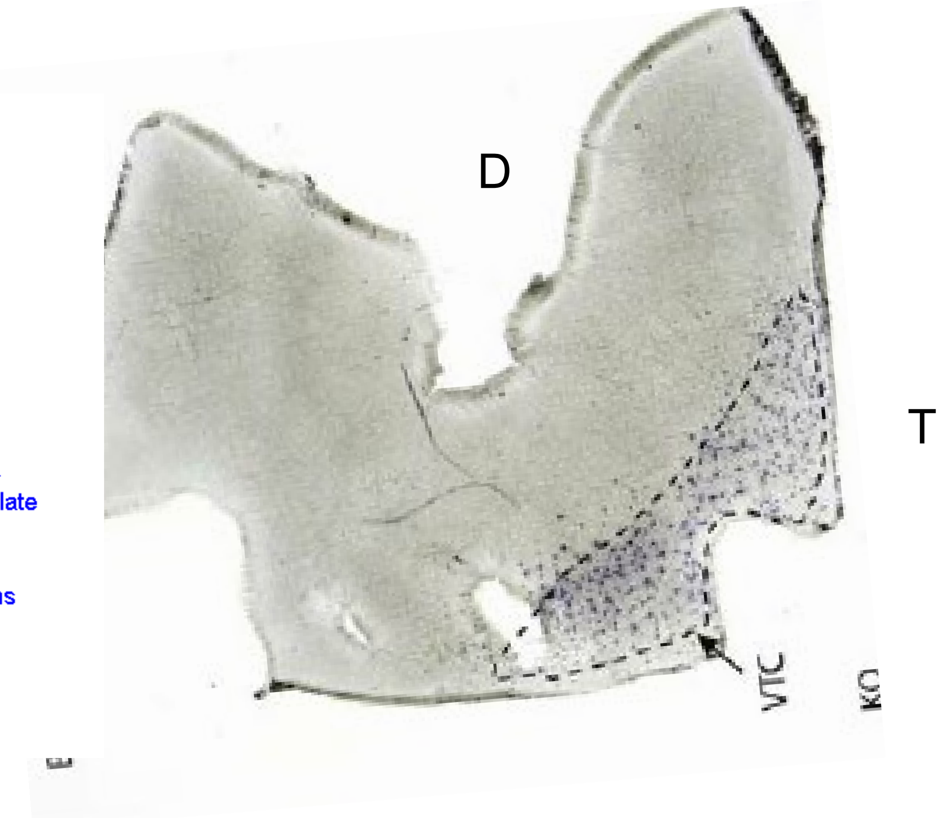
Right tract is cut

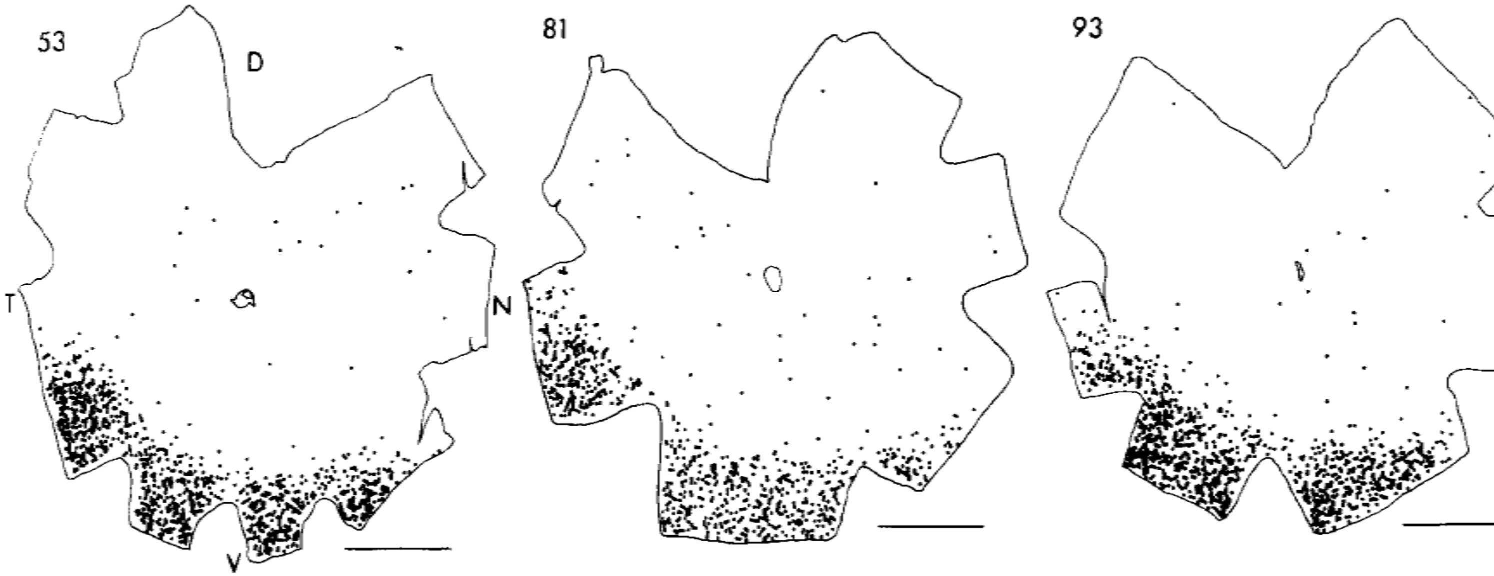


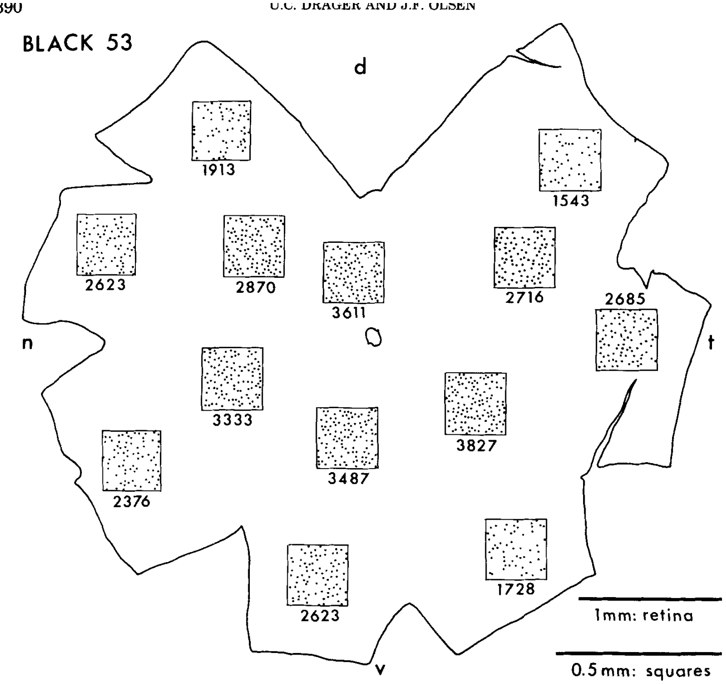


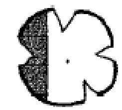
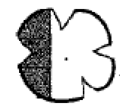
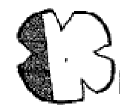
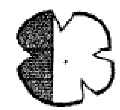
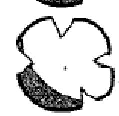
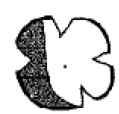



Retina
Optic nerve
Optic chiasma
Lateral geniculate nucleus
Optic radiations
Visual cortex


D
T
VTC


53
D
T
N
V
81
93


BLACK 53
d
1913
1543
2623
2870
3611
2716
2685
n
t
3333
3827
2376
3487
2623
1728
1mm: retina
0.5mm: squares
v

Species	Total ganglion cells	No. ipsilaterally projecting ganglion cells in the entire retina	% ipsilaterally projecting ganglion cells in the entire retina	Region containing ipsilaterally projecting ganglion cells	% ipsilaterally projecting cells in temporal retina	Binocular overlap (horizontal)
Macaque	530,000	184,800	35		100	140 deg
Cat	190,000	33,060	17		75	120 deg
Ferret	74,000	6030	8		90	80 deg
Quokka	205,600	20,600	10		70	80 deg
Rat	110,000	8250	7.5		25	80 deg
Mouse	48,000	800	2		15	40 deg
Dunnart	77,000	15,000	20		77	140 deg

[a]References—macaque: Fukuda et al., 1989; cat: Illing & Wässle, 1981; ferret: Morgan et al., 1987; Henderson, 1985; quokka: Harman & Jeffery, 1992; mouse: Dräger & Olsen, 1980; rat: Jeffery et al., 1981; dunnart: this study. Scales = 2 mm.

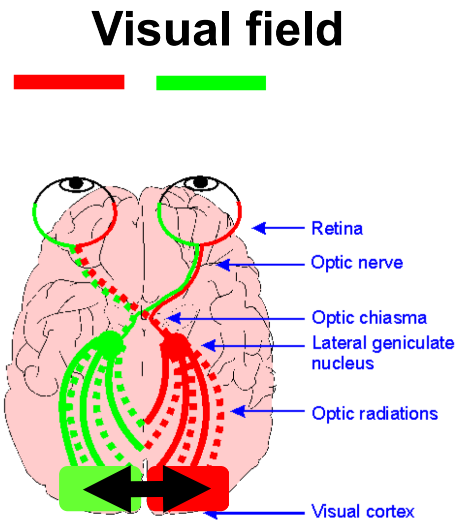
Lateralisation is important: different sides of the brain have different specialisations:

- **Language (Broca's area, Wernicke's area)**
- **Non human behaviours**

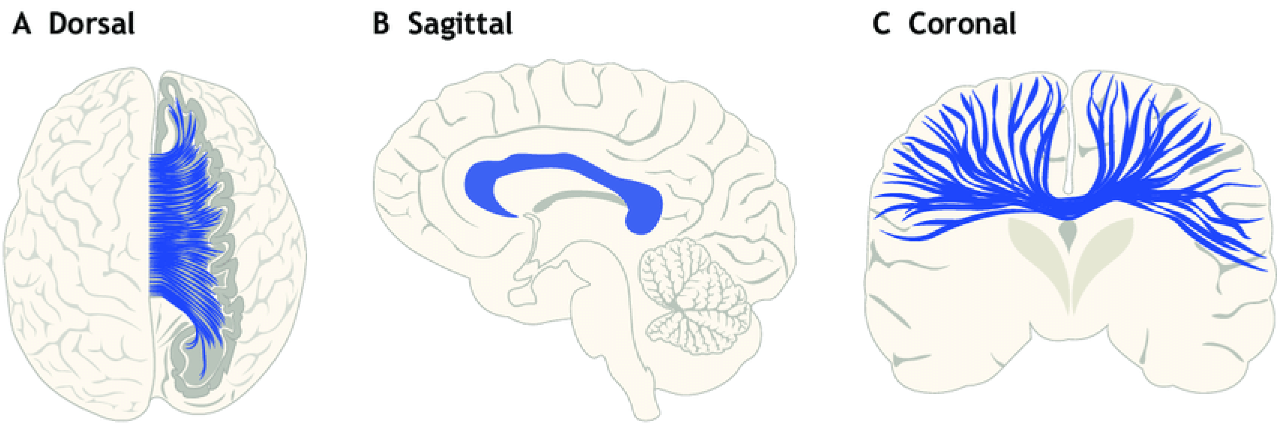
But both sides also have to work together:

- **Hearing**
- **Vision**

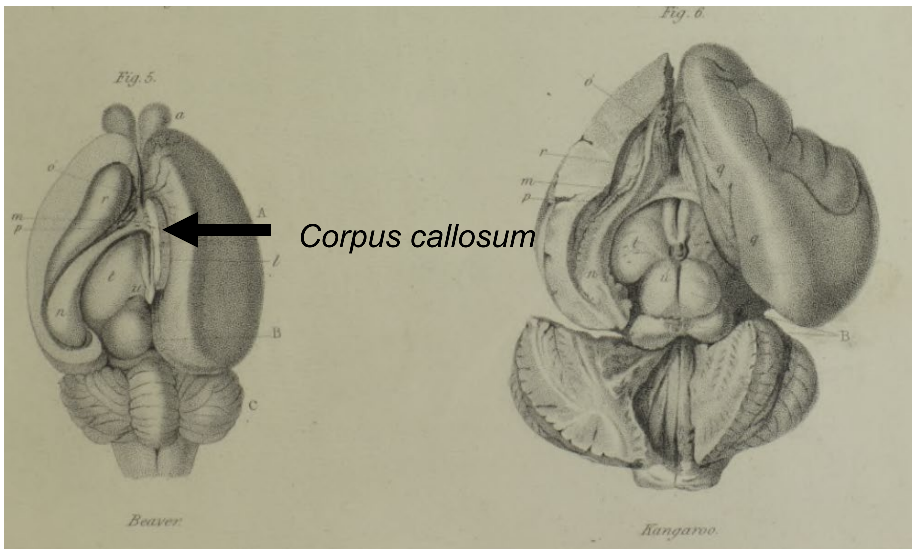
The corpus callosum connects the hemispheres



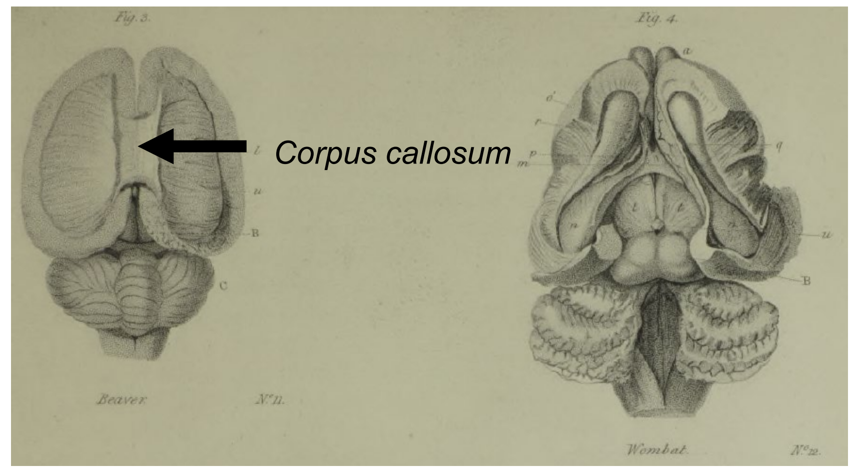
Corpus callosum



Marsupials lack a corpus callosum!



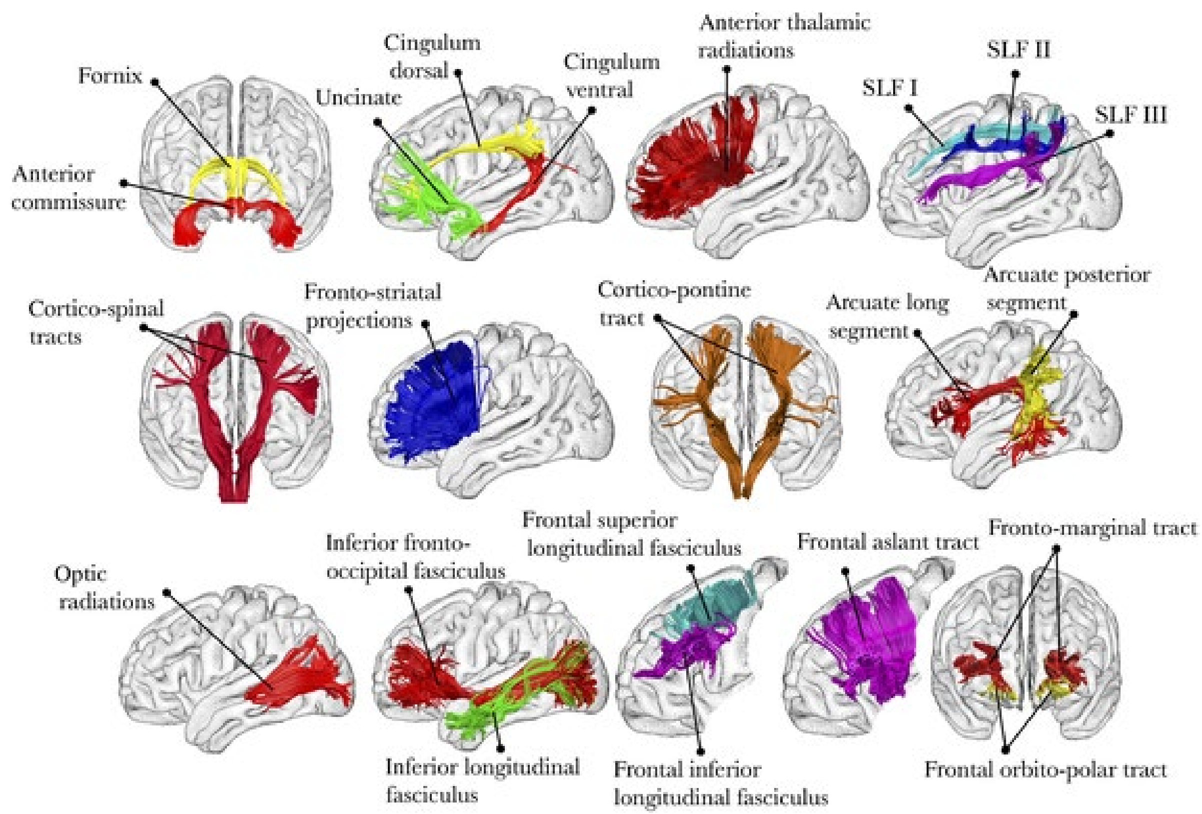
Beaver Kangaroo

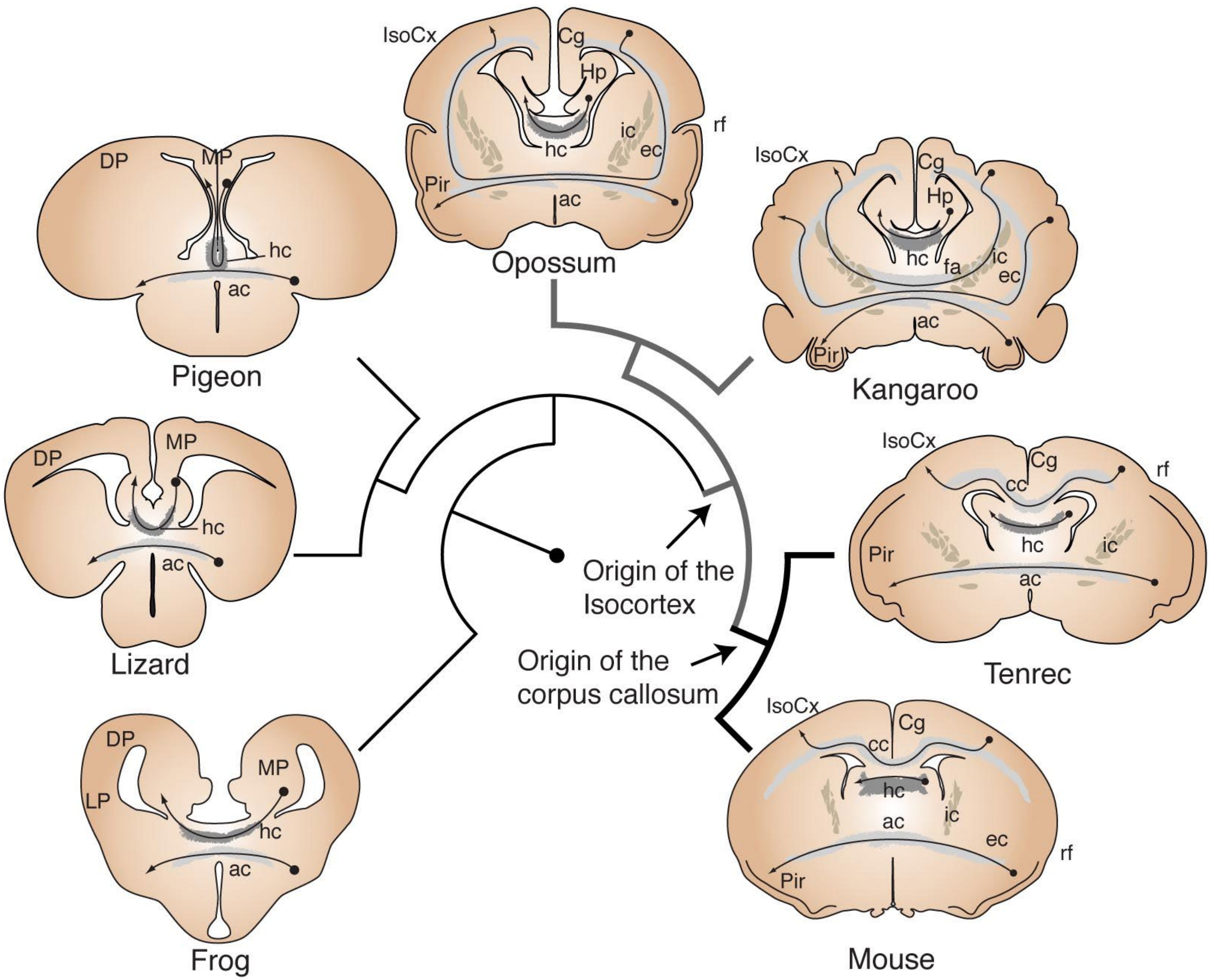


Beaver Wombat

White matter tracts = axon bundles

Corpus callosum
Optic chiasm
Anterior commissure
Corticospinal tract
…



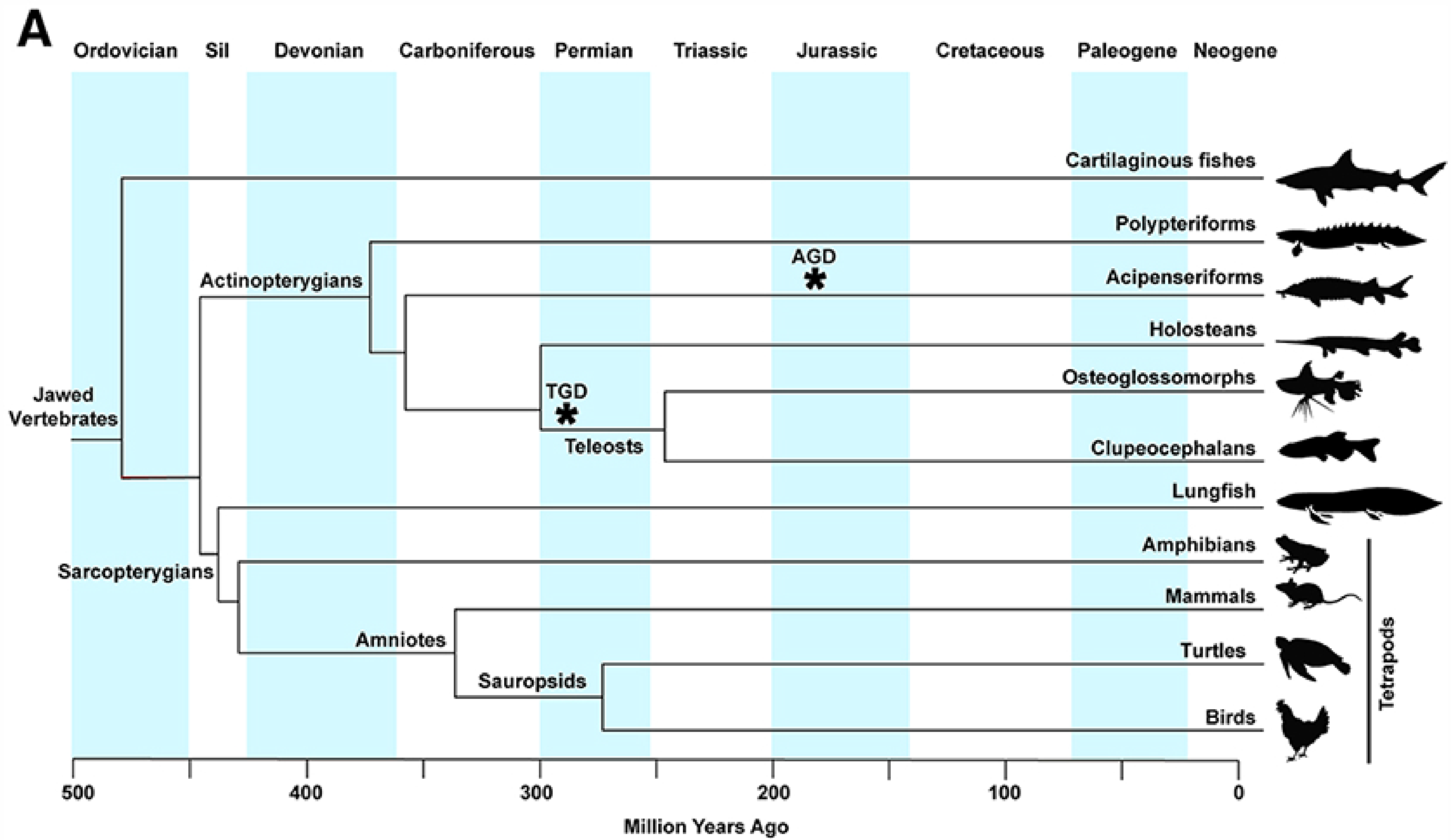


IsoCx
Cg
Hp
rf
ic
hc
ec
Pir
ac
Opossum
DP
MP
hc
ac
Pigeon
IsoCx
Cg
Hp
hc
fa
ic
ec
ac
Pir
Kangaroo
DP
MP
hc
ac
Lizard
IsoCx
Cg
cc
rf
Pir
hc
ic
ac
Tenrec
Origin of the Isocortex
Origin of the corpus callosum
DP
MP
LP
hc
ac
Frog
IsoCx
Cg
cc
hc
ac
ic
ec
rf
Pir
Mouse

But what about fish?

Bilateral vision preceded terrestrial life

Science. 2021 April 09; 372(6538): 150–156.
doi:10.1126/science.abe7790.



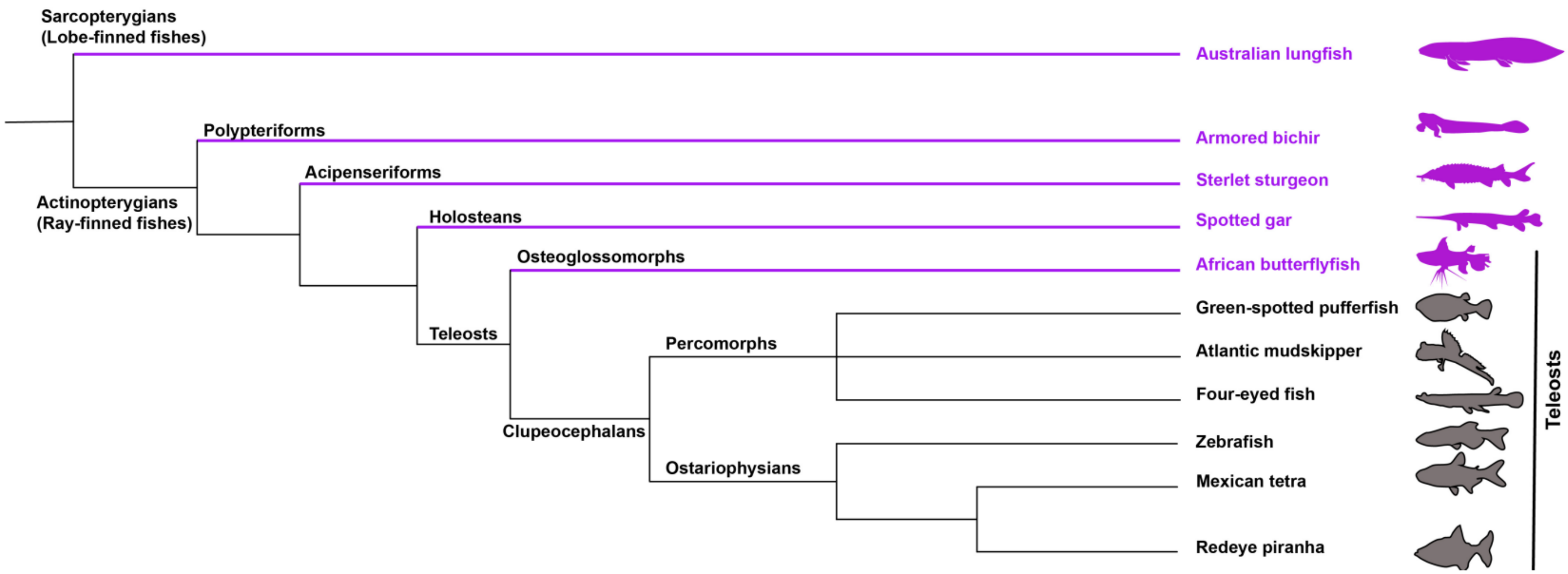
(Asterisks indicate whole genome duplication events in the teleost (TGD) and sturgeon (AGD) ancestors)

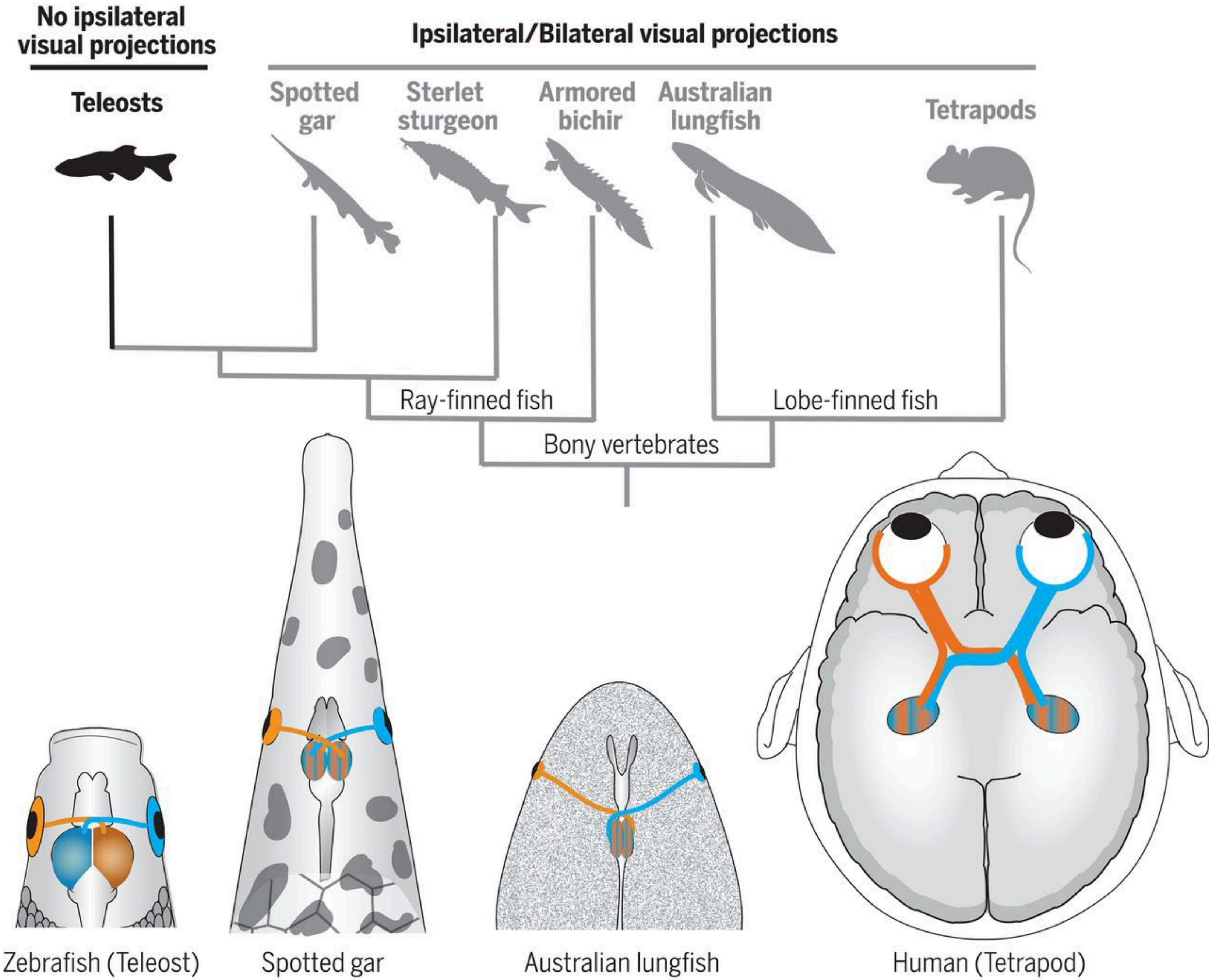
Clupeocephalan lineage
fully crossed: the nerves pass over each other

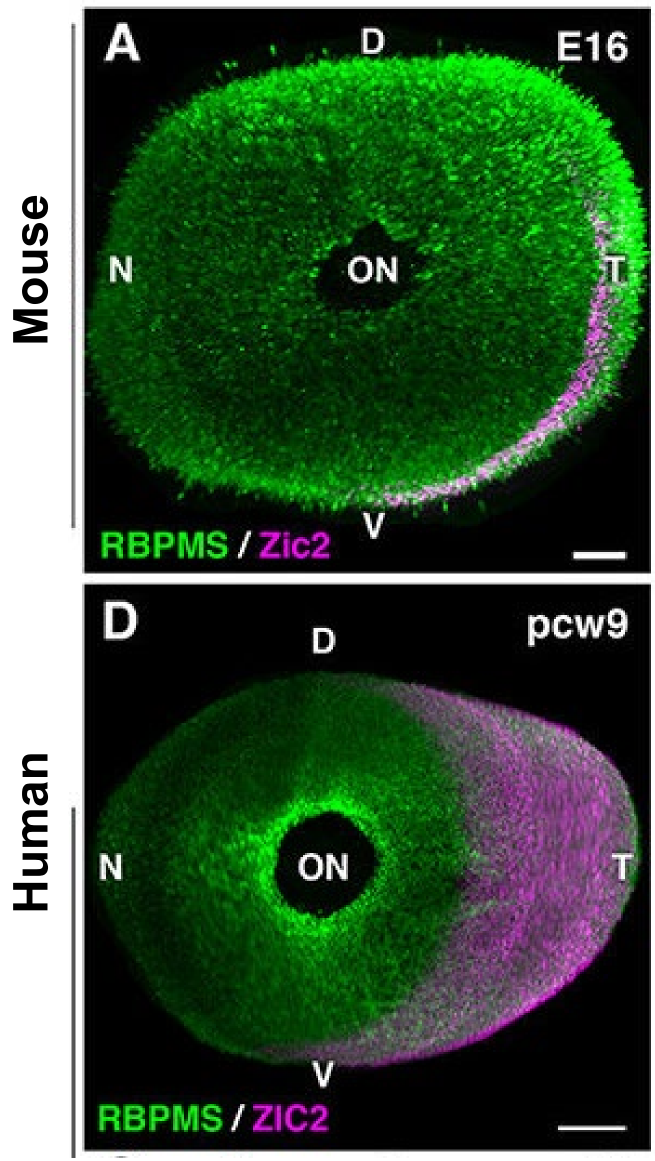
Ray finned fishes: Holosteans and Acipenseriforms
Partial decussation

Fish with ipsilateral visual projections

Fish without ipsilateral visual projections

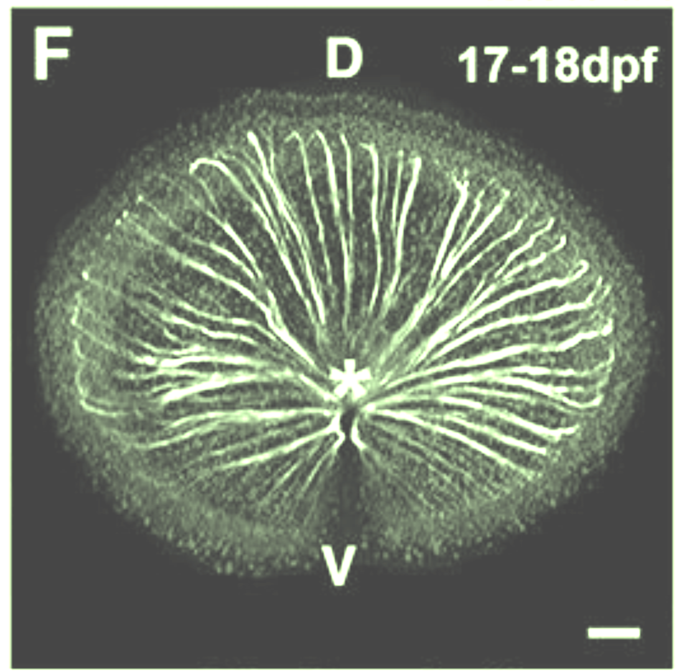



No ipsilateral visual projections
Ipsilateral/Bilateral visual projections
Teleosts
Spotted gar
Sterlet sturgeon
Armored bichir
Australian lungfish
Tetrapods
Ray-finned fish
Lobe-finned fish
Bony vertebrates
Zebrafish (Teleost)
Spotted gar
Australian lungfish
Human (Tetrapod)



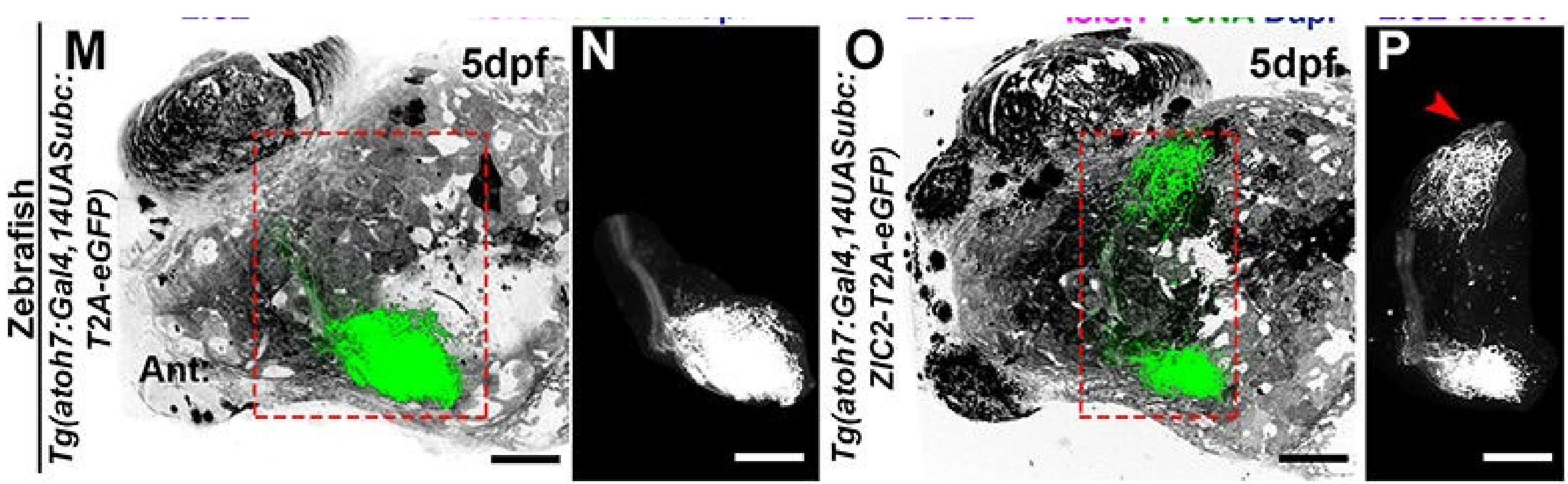
Zic2 expression defines the ipsilaterally projecting RGCs in mammals

But not in fish!



Spotted gar

Zic2 over-expression creates a population of ipsilaterally projecting RGCs in fish



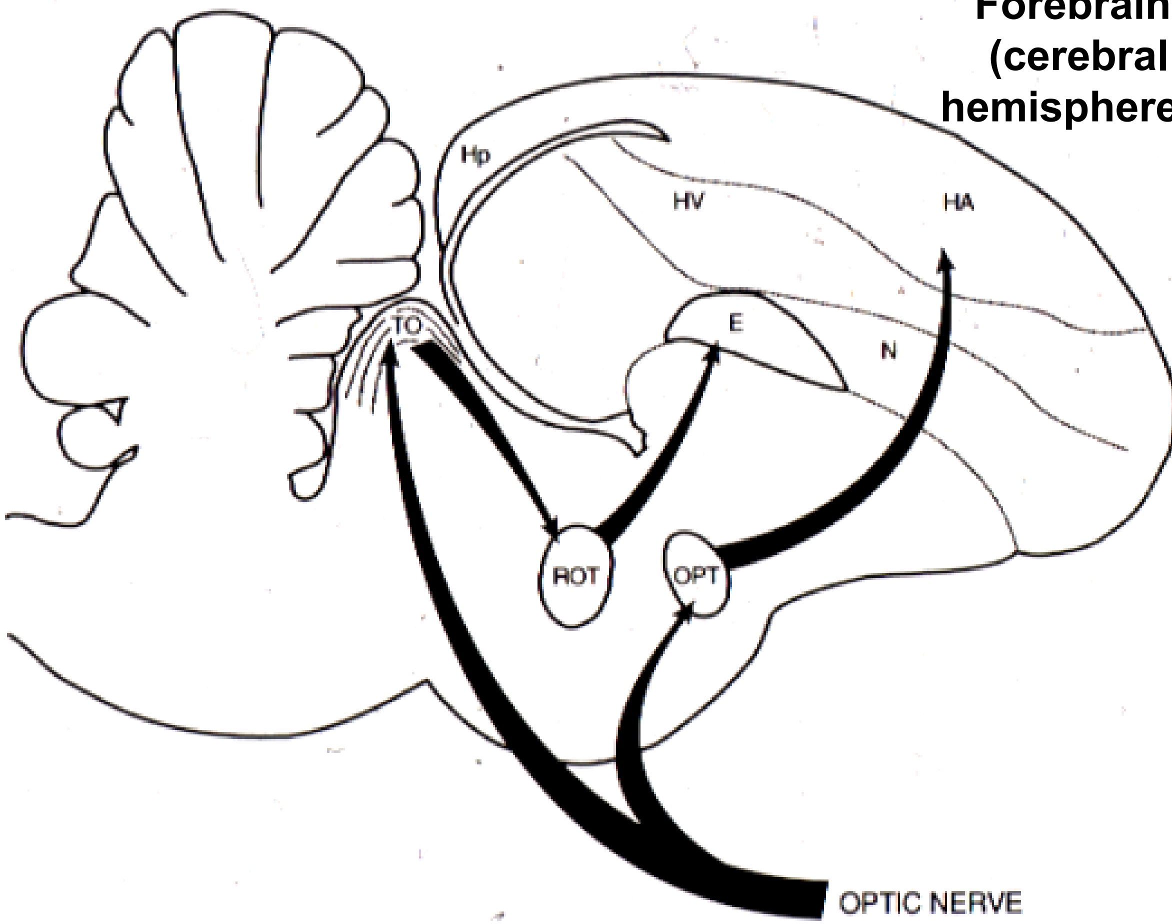
So how do fish with no ipsilateral projections integrate information from both eyes?

WHAT ARE STRUCTURES IN BRAIN THAT UNDERLIE VISUAL LATERALIZATION IN CHICKS?

•Pathways from eye to both diencephalon (OPT) and to mid-brain (TO = tectum) are similar on each side
•Projections from diencephalon to forebrain differ between sides (diencephalon = thalamus)

Forebrain, (cerebral hemispheres)

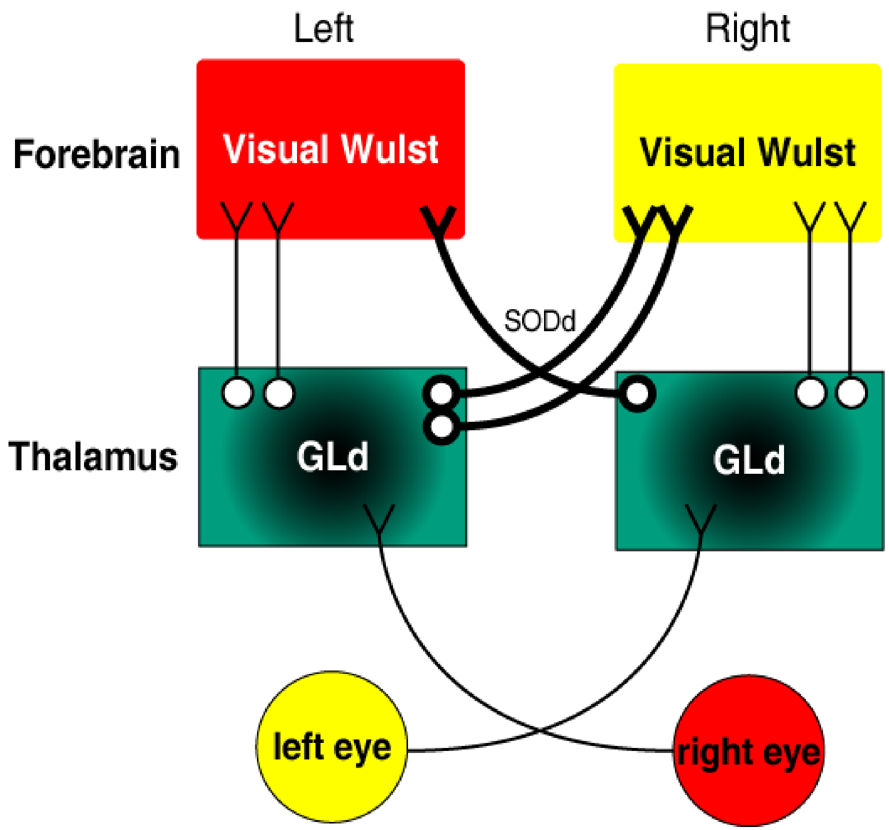
Caudal (back)



Rostral (front)

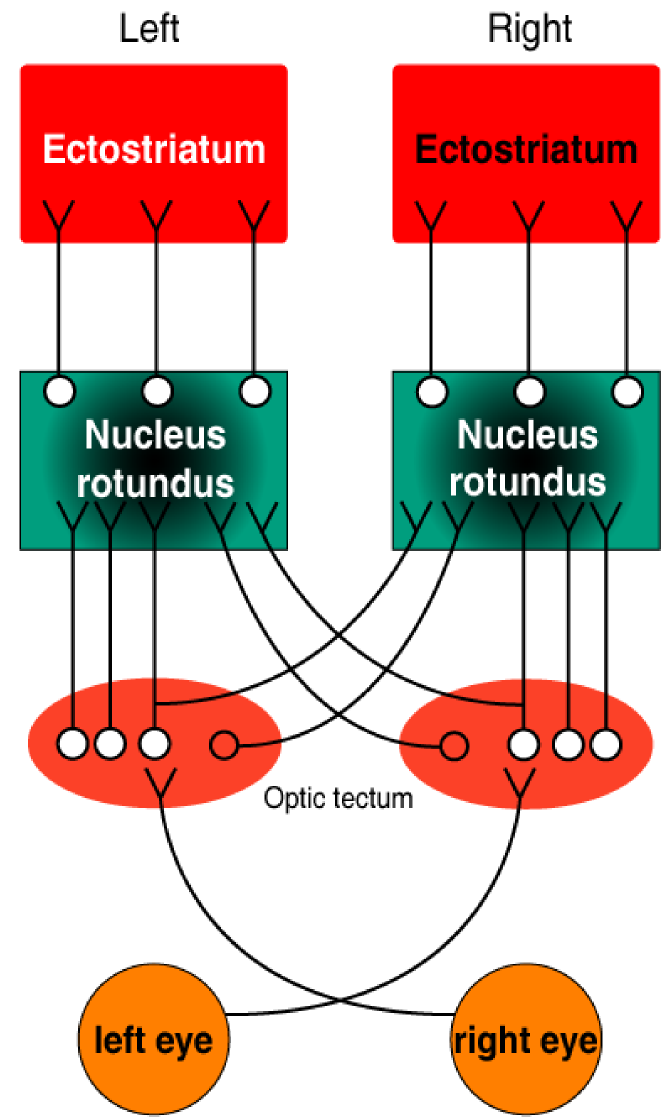
(from the retina)

Pathway via thalamus

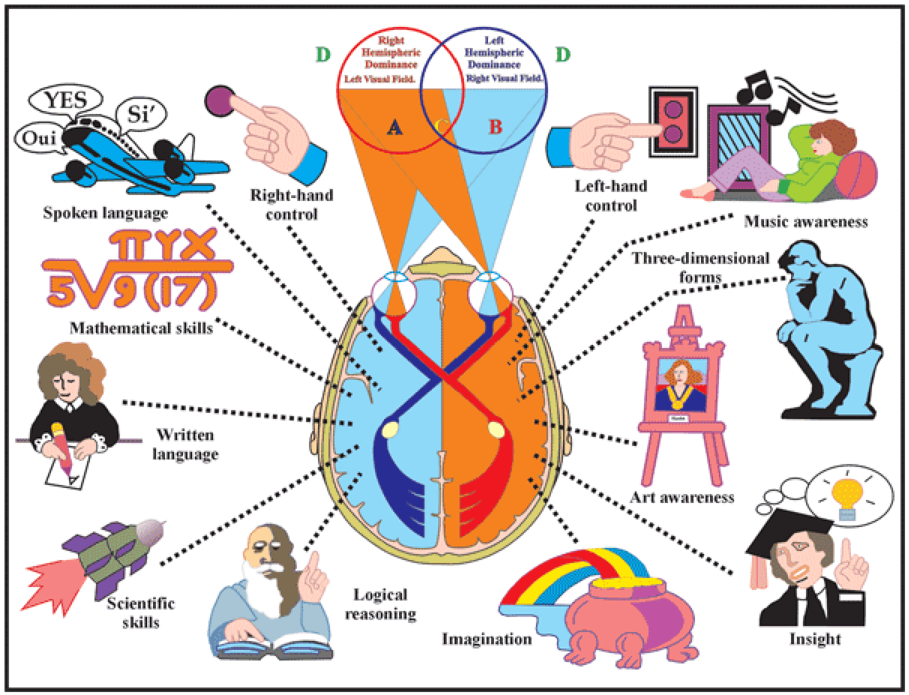


SOD =Supra-optic decussation

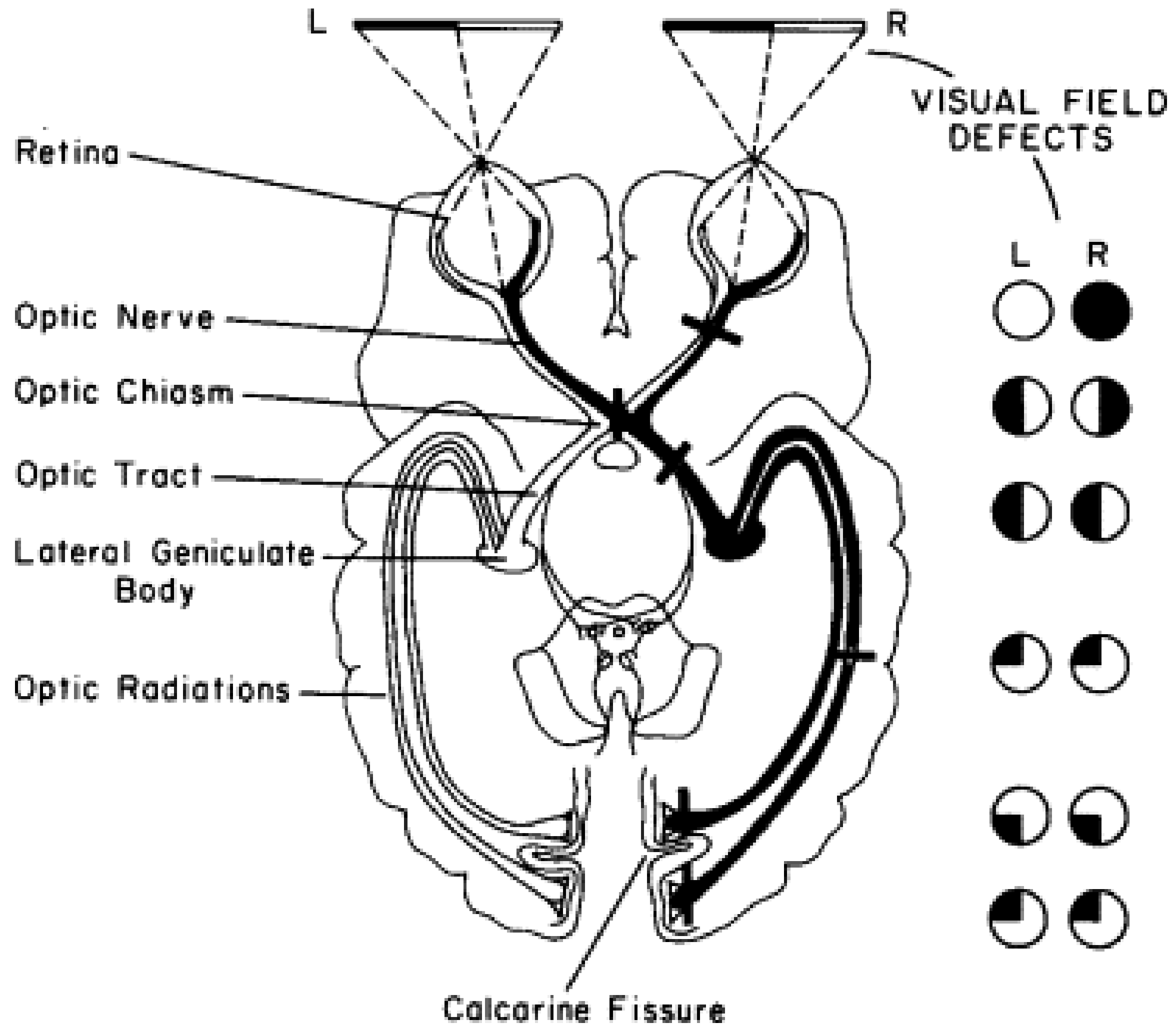
Pathway via tectum



Left vs right side of the brain



+ Roger Sperry: split brain experiments


L
R
VISUAL FIELD
DEFECTS
Retina
Optic Nerve
Optic Chiasm
Optic Tract
Lateral Geniculate
Body
Optic Radiations
L
R
Calcarine Fissure

+ Blindsight